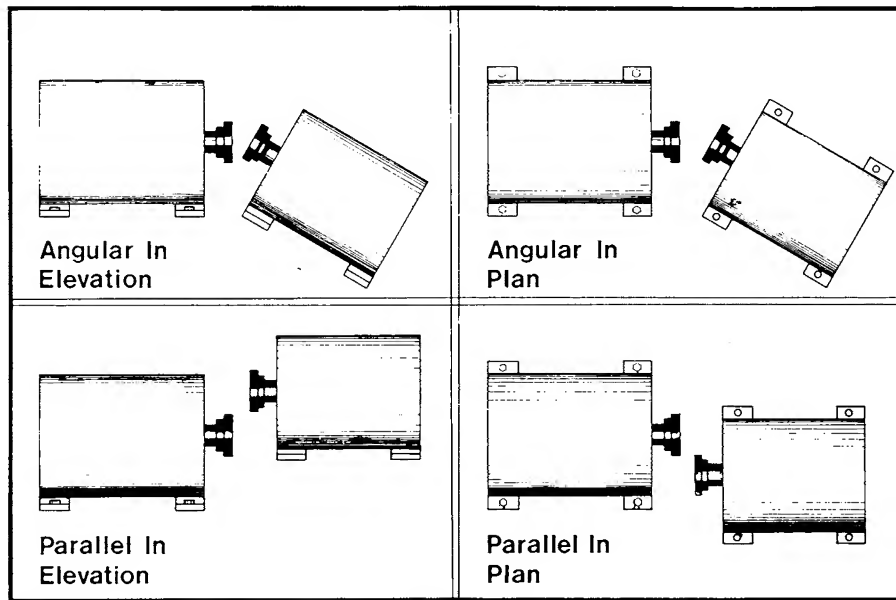


THE FOUR EASY STEPS TO GOOD SHAFT ALIGNMENT



STUDENT WORKBOOK

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GENERAL GUIDELINES TO STUDENTS

This training unit consists of a video tape presentation with an accompanying workbook. The video program is divided into sections. After each video tape section, you will be directed to the workbook where you complete an exercise (answer questions and do readings).

This training program takes approximately two hours to complete.

The recommended sequence is as follows:

- (1) After the administrator gives the introductory remarks, the student reads the objectives.
- (2) The student briefly discusses the objectives with the administrator and other class members.
- (3) The videotape is turned on and the student views the material. Upon completion of tape Section I, the tape is turned off. The student opens the workbook, reads the questions and writes the answers directly in the workbook. When the group has completed the workbook questions, the administrator will review and discuss the material just completed.
- (4) When there is no further discussion, the administrator will start the videotape for Section 2. When this is completed, the tape will be turned off and again the Students return to the workbook.

- (5) Work through all sections in this manner.
- (6) A quiz covering the material in the entire unit will be administered by the instructor after the unit has been completed.
- (7) In the event that the program is to be self-administered, the student will refer to the administrator's guide.

PROGRAM OBJECTIVES

On completion of training on "The Four Easy Steps To Good Shaft Alignment", the student should be able to:

1. Understand the difference between aligning couplings and aligning shafts.
2. Calculate the exact amount of equipment movement required to correct any given amount of shaft misalignment.
3. Express an understanding of the tools of alignment.
4. Understand the advantages of using alignment brackets.
5. Express an understanding of the effect of angular misalignment on Parallel Alignment Readings.
6. Calculate and compensate for the effect of Machine Thermal changes on Alignment.
7. Align light or heavy equipment within the close tolerances specified here-in.
8. Dowel the equipment footings to the sole plates.
9. Submit a Comprehensible Alignment Report.

NOTES

HIGHLIGHTS

SECTION #1

- Explanation of Elevation & Plan Views
- The Four Positions of Misalignment
- Proper Sequence of Alignment Steps
- Angular Misalignment Tolerance
- Shaft Alignment vs Coupling Alignment
- Calculating Required Movement
- Use of Dial Indicator on Equipment Footing
- Selecting the Correct Pivot Point
- Maintaining Shaft End Clearance

SECTION #2

- Instruments & Tools
- Advantages of Alignment Brackets
- Checking Alignment Bracket Sag

SECTION #3

- How To Use The Dial Indicator
- How To Use Alignment Brackets
- How To Check Angular Alignment
- Parallel Misalignment Tolerance
- Effect of Angular Misalignment On Parallel Alignment Readings
- Screw Jack vs Hydraulic Jack
- Alignment Report

SECTION #4

Hot Alignment

Calculating The Effect of Thermal Changes On Machine Alignment

How To Take Advantage of Allowable Alignment Tolerances

How To Compensate For Coupling Face Wobble or Distortion

Doweling Machine Footings

Safety

Correction Factors For Dial Indicator Set At Angle

SECTION ONE

NOTES

SECTION ONE
THE FOUR EASY STEPS TO
GOOD SHAFT ALIGNMENT

Most Alignment procedures are very complicated and hard to follow. Some attempt to correct all four positions of alignment with one set of readings and one move. Most make heavy use of algebraic calculations and graphs and are easily subject to error.

This procedure, "The Four Easy Steps To Good Shaft Alignment" is simple and straight-forward. These steps performed in sequence will eliminate guess work and backtracking and will consistently result in good shaft alignment.

We'll begin by outlining the four easy steps and the simple calculations that are basic to the procedure. Then, we'll cover the subjects that are common to all alignment procedures such as:

- A. Taking alignment readings.
- B. Pre-aligning equipment to compensate for thermal changes.
- C. Calculating for coupling face runout.

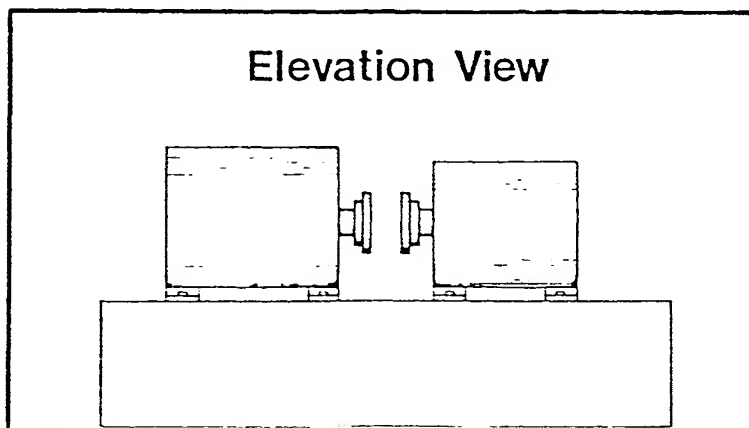


FIGURE 1

Blueprint drafting standards established long ago that an elevation view is seen when standing beside an object looking straight ahead at the side or end of the object, (See Figure #1).

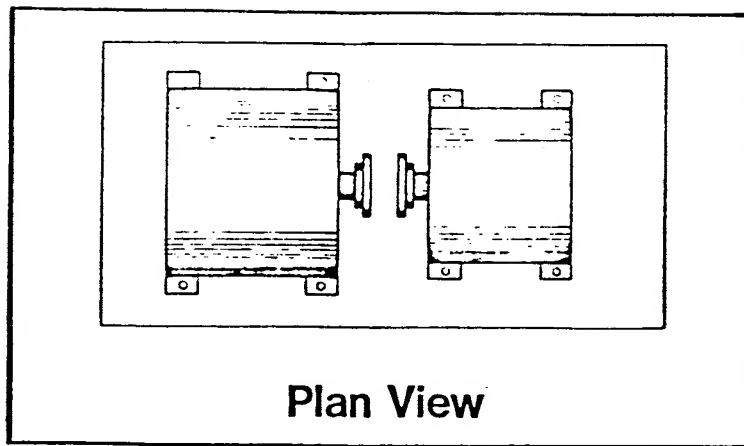


FIGURE 2

A "plan" view is seen when looking from above straight down on the object, (See Figure #2).

Since everyone in the service and building trades must be familiar with blueprints, the terms "Elevation" and "Plan" should be less confusing than some others which could be used.

Following are the four positions of misalignment which can exist between two pieces of rotating equipment.

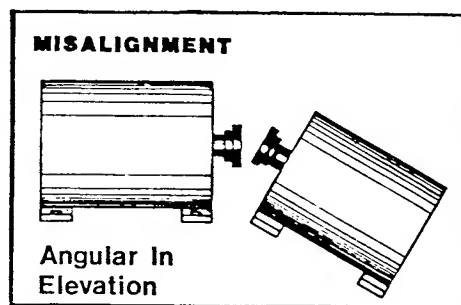


FIGURE 3

Position #1 is angular misalignment in elevation (Figure #3). This position must be corrected first. If any of the other three are corrected ahead of this one, they could be lost when this one is corrected. This correction is made with shims and will not change as the other positions are corrected.

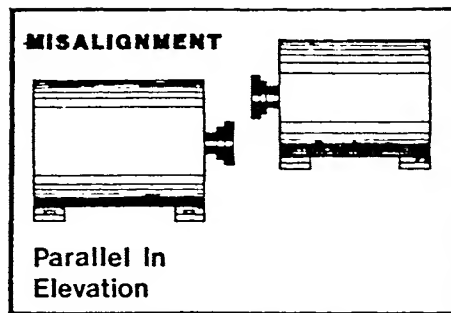


FIGURE 4

Position #2 is parallel misalignment in elevation (Figure #4). The correction here is straight up or down, involving equal amounts of shim stock under each footing. If Position #3 or #4 is corrected ahead of #2, one or both could be lost while correcting #2.

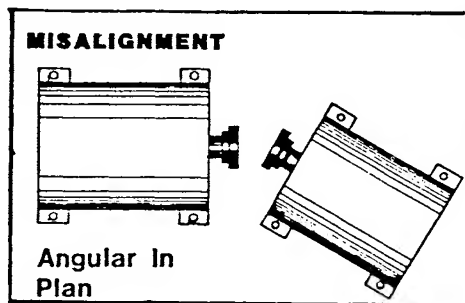


FIGURE 5

Position #3 is angular misalignment in plan (Figure #5). The correction here will be to slide the rear end of the movable equipment sideways on the sole plate to correct the angle. This move must come ahead of #4 because #4 would definitely be lost in the process of correcting #3.

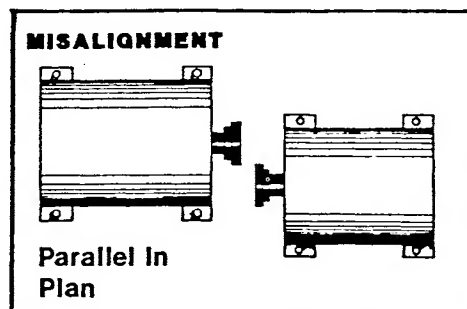


FIGURE 6

Position #4 is parallel misalignment in plan (Figure #6). This can be corrected without losing the angular alignment of position #3 by using a dial indicator at the footings and sliding the equipment straight over an equal amount at each end.

As you can see, there are four positions of possible misalignment. Consequently, there are four steps to good shaft alignment. These must be taken in the exact sequence shown to avoid disturbing one alignment position while correcting another.

It should be noted that the stationary unit is frequently a compressor or pump. The movable unit is most often the driver, such as a motor, turbine, etc. There may be a gear between the stationary and movable units which is movable. It should be aligned first.

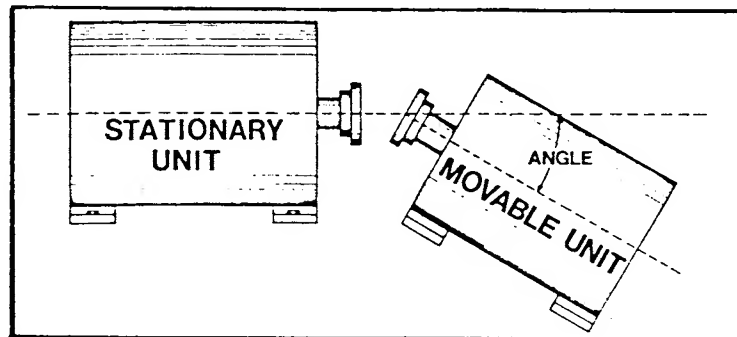


FIGURE 7

The Misalignment shown in Figure #7 is called angular misalignment because the shaft of the movable unit runs off at an angle to the shaft of the stationary unit. Some equipment owners specify that this angle shall not exceed .0003" (three- ten/thousandths of an inch) per inch of travel along the shaft. This means that at a point 10" along the shaft from the coupling, it shall not slope away from the other shaft more than .003".

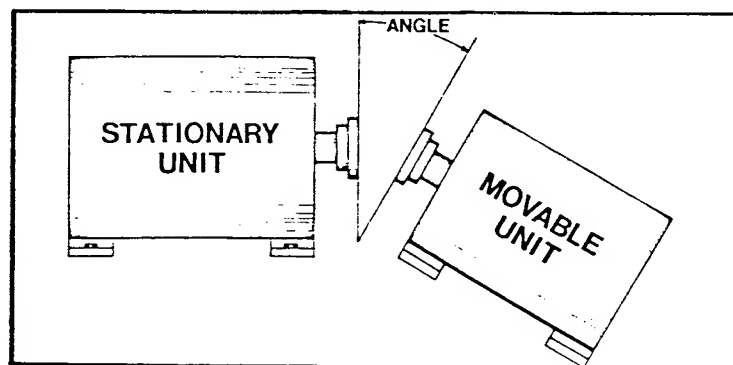


FIGURE 8

Note too, that the faces of the coupling hubs are also at an angle to each other (See Figure #8). This is not the reason this is called angular misalignment. We are aligning shafts, not couplings. Always keep this in

mind even when taking alignment readings off the face or O.D. of the coupling hub.

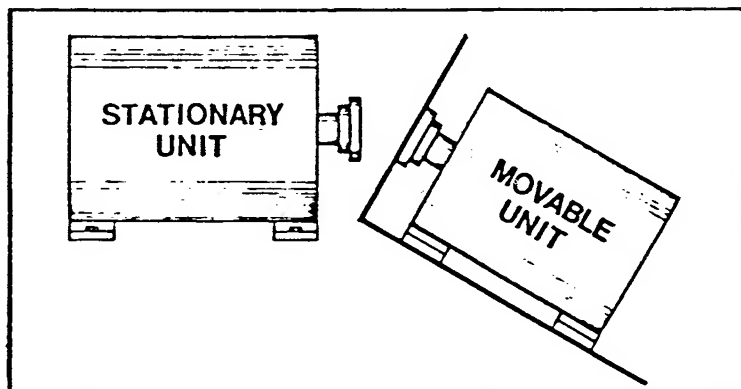


FIGURE 9

As shown in Figure #9, the face of the coupling hub is always at a right angle (90°) to the bottom of the equipment footings. This will remain a constant no matter how high, low, short or long the shaft may extend out of the unit and no matter what moves we make to the equipment.

Now we will run through a hypothetical alignment using the four steps and show how to calculate the amount of each move.

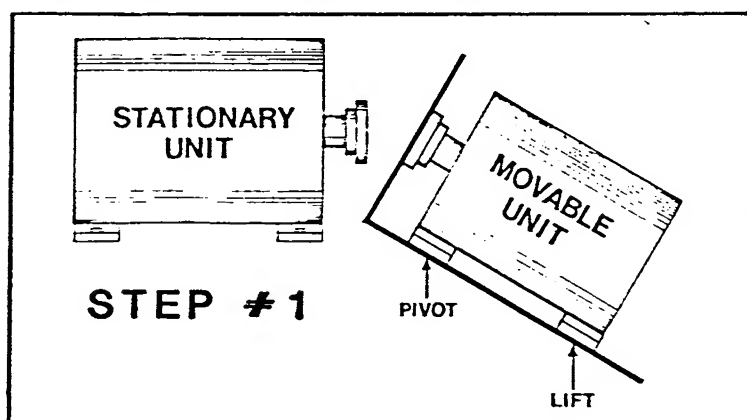


FIGURE 10

Starting with step #1, angular in elevation (See Figure #10), assume readings have been taken across the face of the coupling hub, which is 4" diameter, and it is open at the top .005" more than at the bottom.

Lifting the rear footings of the movable unit would tend to close the coupling at the top. To do this, the pivot point becomes the front footings. It is obvious then that the distance between the rear footing and the pivot point (front footing) is a factor in how much the coupling

faces will close at the top for any given amount of lift at the rear footings.

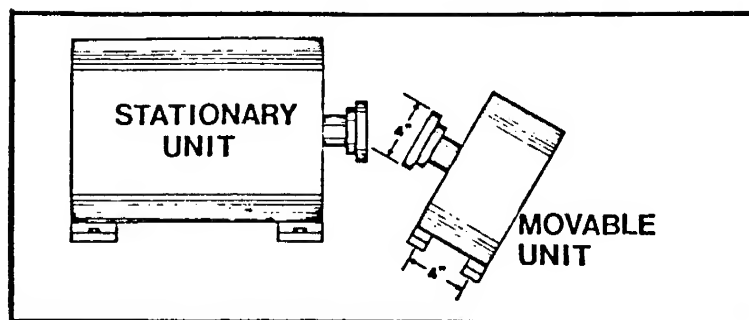


FIGURE 11

As shown in Figure #11, with a 4" diameter coupling, if the distance between the front and rear footings was also 4", then it would be a 1 to 1 ratio and lifting the rear footing .005" would close the coupling .005" at the top. If the distance was 8" between footings, the ratio would become 2 to 1 and the rear footings would have to be raised .010" to close the 4" diameter coupling .005" at the top.

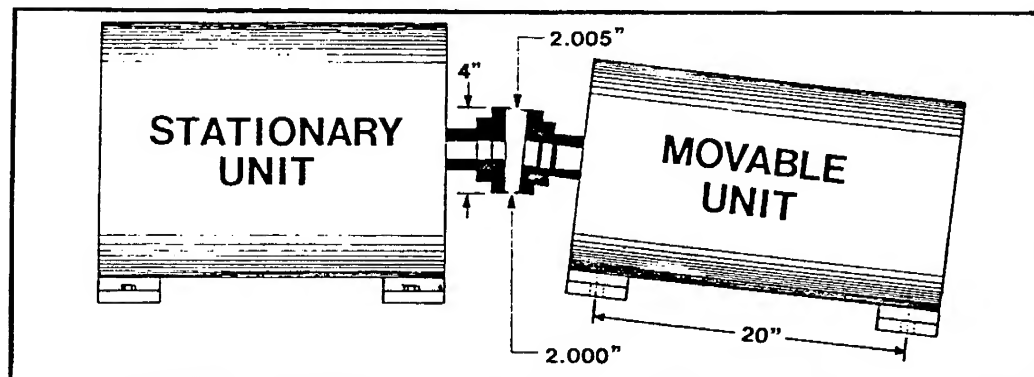


FIGURE 12

The conditions shown in Figure #12 are more realistic. We have assumed the coupling is 4" diameter, the distance between front and rear footings is 20", and the opening at the top of the coupling is .005" larger than at the bottom. We make a simple calculation. "How many times will the coupling diameter go into the distance between the front and rear footings?" The answer obviously is 5 times. So five times .005" tells us that a shim .025" thick placed under each rear footing will bring the coupling into good angular alignment in elevation.

The distance between footings is measured from center to center of the hold-down bolts.

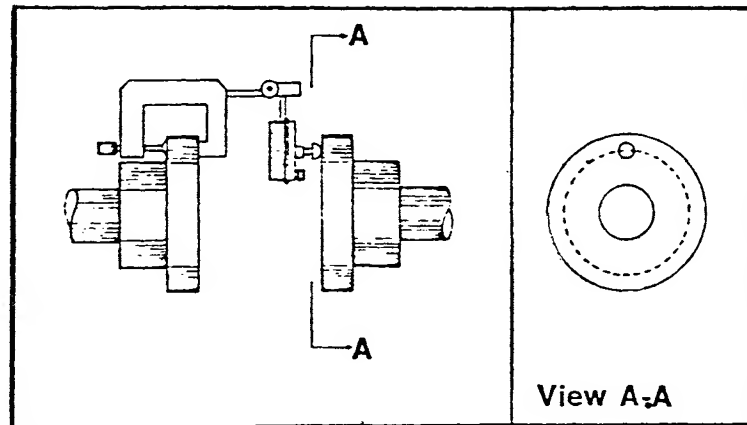


FIGURE 13

In our hypothetical measurements for Step #1, we assumed that the alignment check was made with a dial indicator with its button on the coupling hub face very close to the edge of the 4" diameter (See Figure #13). Actually, the indicator button could be placed closer to the shaft center or further out from center if the coupling hub face is larger in diameter.

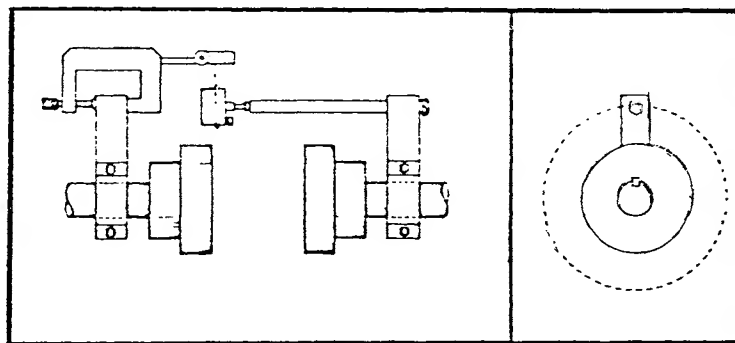


FIGURE 14

The reading could even be taken off brackets attached to the shaft as shown in Figure #14. Now, the dial would rotate through a circle much larger than the coupling hubs.

It is actually the diameter of the circle through which the button of the dial indicator rotates that must be divided into the distance between the front and rear footings of the movable unit.

After adjusting misalignment, always recheck to confirm that the correction was properly made.

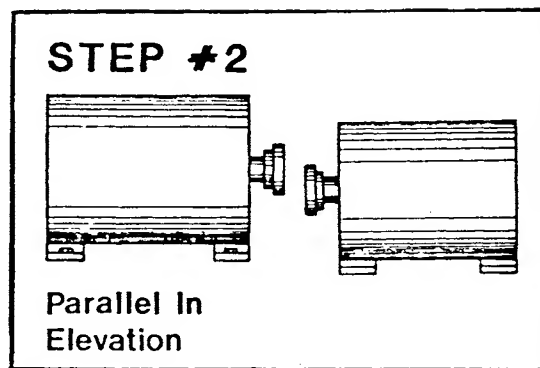


FIGURE 15

Step #2, "Parallel in Elevation", is very simple. With a dial indicator, check to see how high or low the shaft of the movable unit is in relation to the shaft of the stationary unit.

We will get into detailed use of the dial indicator later. For now, let's assume the shaft of the movable unit is .012" below the shaft of the stationary unit. Placing a .012" thick shim under each of its footings will bring the shafts into good parallel alignment in elevation.

Steps 1 & 2 are complete. These were both obtained with shims so they will not be lost while performing steps #3 and #4.

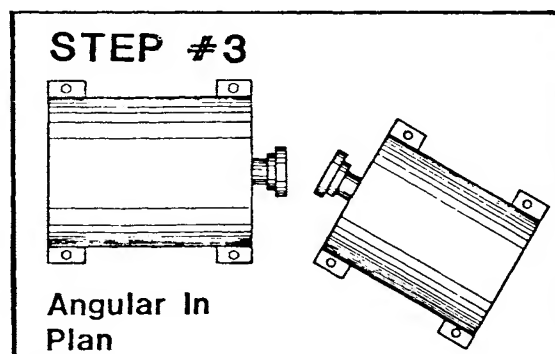


FIGURE 16

Step #3 corrects angular misalignment in plan. The calculation used in step #1 can be used here. Let's assume the distance between coupling faces is .008" greater on one side than on the other side. Divide the coupling

diameter (4") into the distance between the front and rear hold down bolts, (20") and multiply by .008" ($20 \div 4 = 5$, $5 \times .008" = .040"$). So the rear end of the movable unit will have to be moved exactly .040".

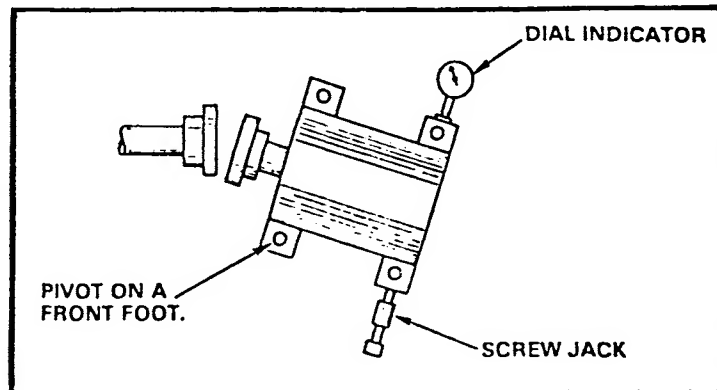


FIGURE 17

To do this, place the dial indicator against the rear footing on the side which has the larger coupling opening as shown in Figure #17. It must be exactly in line with the hold down bolt. Set the indicator on zero.

Place a screw jack in position at the opposite rear footing to move the equipment toward the indicator.

Loosen both rear hold-down bolts and one front hold-down bolt.

Turn the screw jack and move the rear end against the indicator until it registers .040".

Tighten all hold-down bolts and recheck the indicator. If it has changed because of tightening the bolts, then loosen the same three bolts and readjust. It may be necessary to over-shoot or under-shoot the desired reading to have it come out right when the bolts are tightened.

Recheck angular misalignment. This pivoting move (Step #3) can be influenced by burrs on the bottom of very large footings. Burrs may cause the pivot point to be slightly off the exact distance between the hold-down

bolts. The difference would be very slight. But if this happens, recalculate and make a second move. The same percentage error on the second move will bring the alignment well within tolerance.

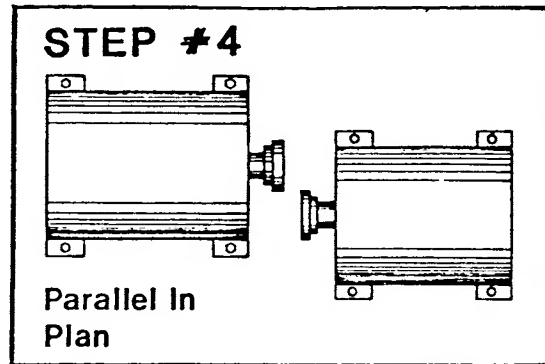


FIGURE 18

Step #4 is to correct parallel misalignment in plan.

With a dial indicator attached to one shaft or coupling and the indicator button on the outside diameter of the other shaft coupling hub, find how much the shafts are offset one from the other. Let's assume it's .045".

Now the trick is to move the movable unit straight over .045" without disturbing the angular alignment made in step #3.

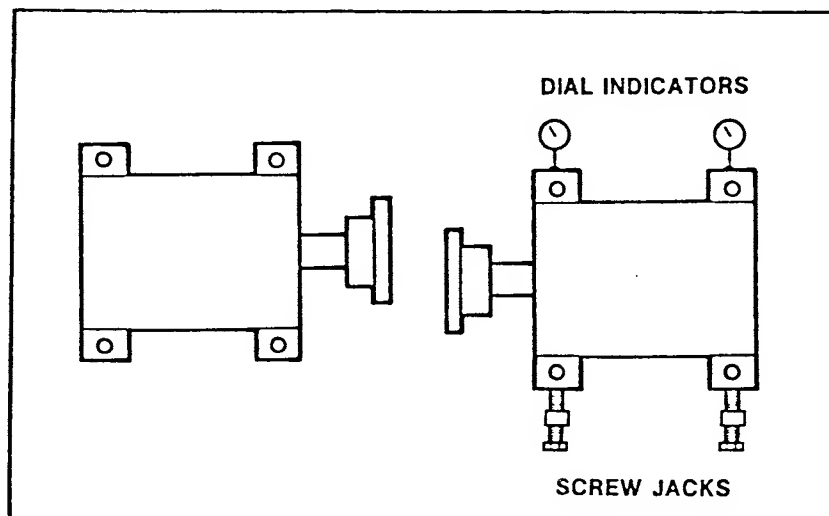


FIGURE 19

If you have two dial indicators and two screw jacks, you can set up and make the move as shown in Figure #19. If there is only one indicator on the job, then use it and the screwjack at the footings the same way you did

in step #3. Move one end of the unit against the indicator until it shows .045". Tighten the hold down bolts and move the indicator and screwjack to the other end of the unit. Loosen three of the hold down bolts and move this end .045". The pivot point must be on the same side of the equipment for each of these moves.

Recheck to be sure parallel alignment is within .002", and that angular alignment has not been disturbed.

This completes the Hypothetical Alignment.

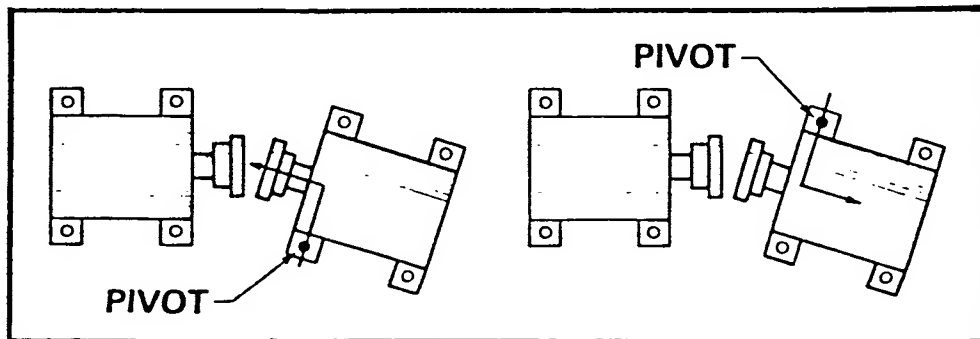


FIGURE 20

When making angular adjustments in plan, the distance between the ends of the shaft will always be affected. This distance is important and should be held very close to the coupling manufacturer's recommendation which is usually stamped on high speed coupling hubs.

Check the distance between the shaft ends, then decide how to make the adjustment.

As shown in Figure #20, pivoting on the front foot on the closed side of the coupling will shorten the distance between the shaft ends, whereas, pivoting on the front foot on the open side will lengthen this distance.

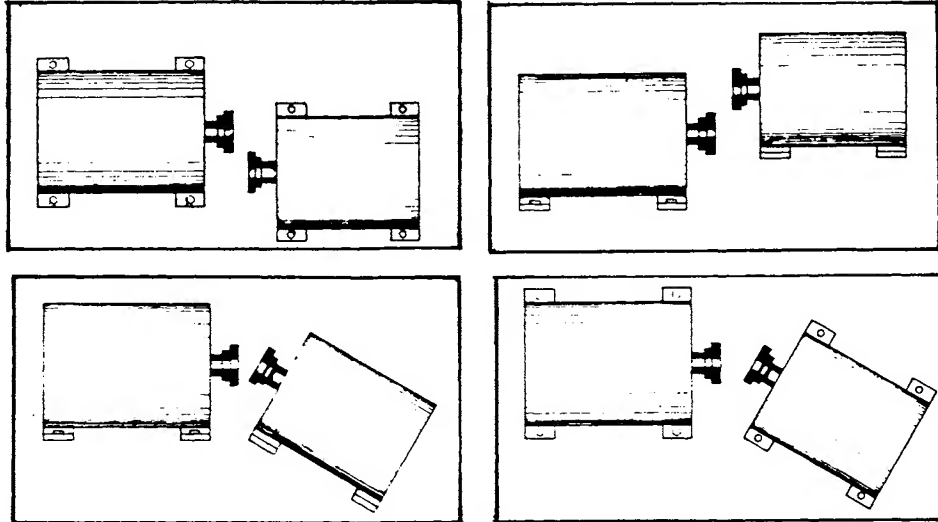
If the distance between shaft ends must remain as is then pivot half the required movement on one front footing and half on the other.

NOTES

SECTION 1

WRITTEN TEST

- There are 4 steps to good alignment. Identify the following by number.



- Check the method by which each of the four steps are corrected.

	Shims	Dial Indicator & Screw Jack
Step #1		
Step #2		
Step #3		
Step #4		

- Circle the Angular Alignment Readings which would be acceptable if taken on a 12" Diameter Circle.

.0015"	.004"	.002"	.005"
.0003"	.0045"	.003"	.0036"

- Readings taken across a 8" diameter coupling show it is open at the top .009" more than the bottom. The distance between front and rear footings is 28". Circle the amount of shim you would put under the rear footings to close the top opening .009".

.0248"	.072"	.028"	.0185"
.0315"	.012"	.020"	.009"

5. To shorten the distance between shaft ends, which side of the movable unit would you pivot on?

☐ The side with the greater coupling opening.

☐ The tight side of the coupling.

6. Write in the correct number for the following:

Step # _____ Angular in Plan

Step # _____ Parallel in Elevation

Step # _____ Parallel in Plan

Step # _____ Angular in Elevation

SECTION TWO

NOTES

SECTION TWO

THE FOUR EASY STEPS TO GOOD SHAFT ALIGNMENT

Now that we know what to do about misalignment, let's review the procedures for taking alignment readings.

This is extremely important. Working with incorrect readings results in waste of time and poor alignment.

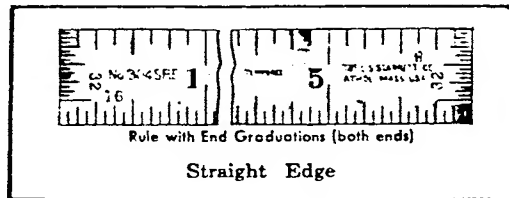


FIGURE 21

Instruments used in checking alignment include a straight edge (Figure #21) which is used mostly for rough alignment and to verify that the misalignment is within the range of the dial indicator.

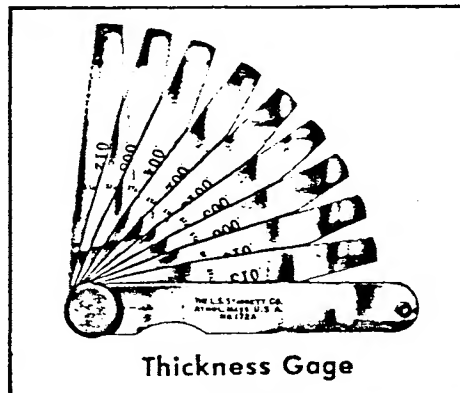


FIGURE 22

A thickness gauge (Figure 22) can be used where coupling hub ends are close together and obstructions prevent the use of a dial indicator and alignment brackets.

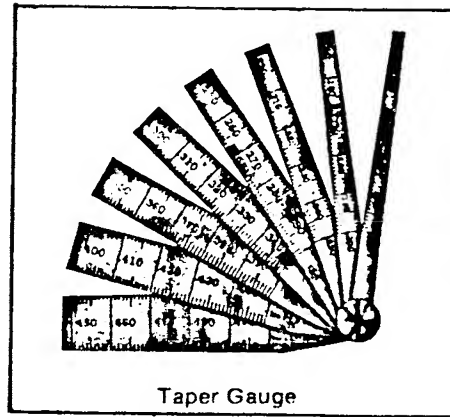


FIGURE 23

Taper gauges (Figure #23) can also be used to check close gaps between coupling hubs. They are faster than thickness gauges and give a direct readout in thousandths of an inch.

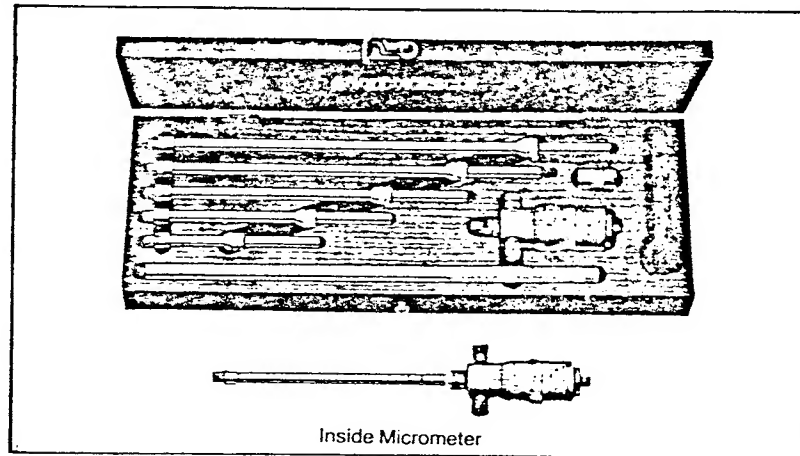


FIGURE 24

Inside micrometers (Figure #24) can be used when coupling hubs are inches apart and there is no dial indicator on the job.

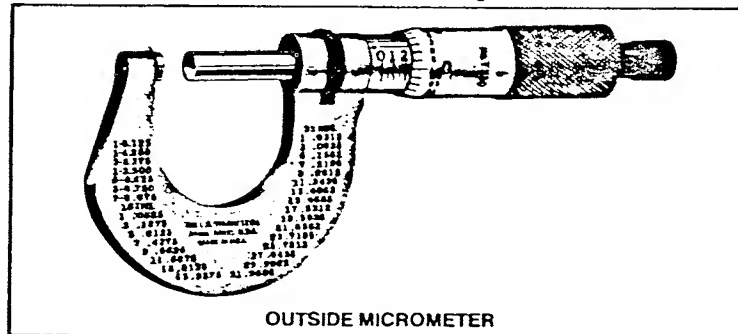


FIGURE 25

The outside micrometer (Figure #25) is necessary for checking the total thickness when using thickness gauges, measurements made with the telescope gauge, and to check shim stock thickness.

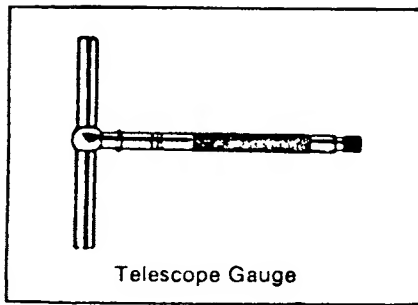


FIGURE 26

The telescope gauge (Figure #26) can be used to check the gap between the coupling hub faces. It is rarely used above one inch because outside micrometers must be on hand to check the telescope length.

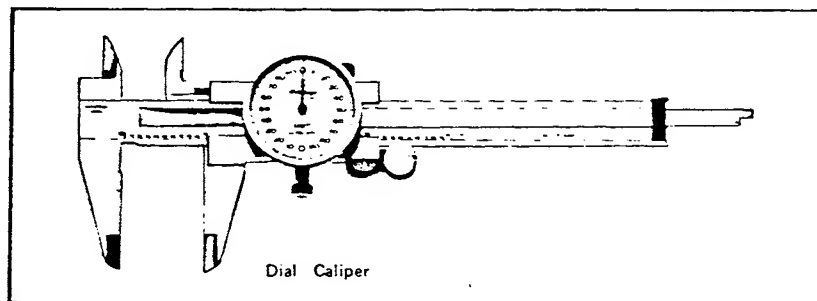


FIGURE 27

The Dial Caliper (Figure #27) may be used to check the gap between coupling hub faces. Because of its length, there seldom is room to use it.

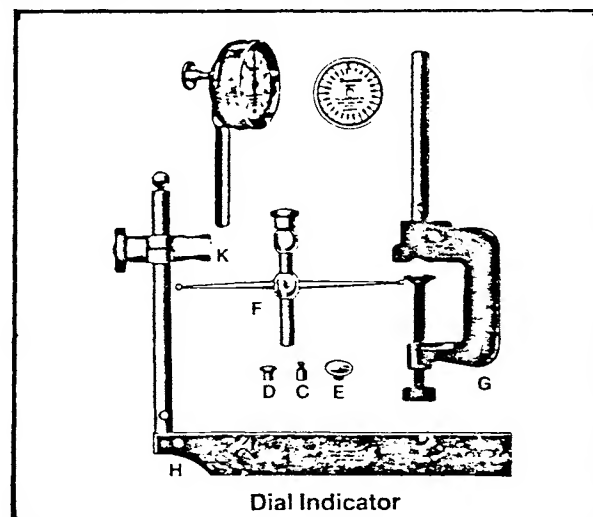


FIGURE 28

This brings us to the dial indicator (Figure #28). It is by far the best instrument to use in taking alignment readings. When used with alignment brackets, all alignment readings can be taken without even opening or disconnecting the coupling.

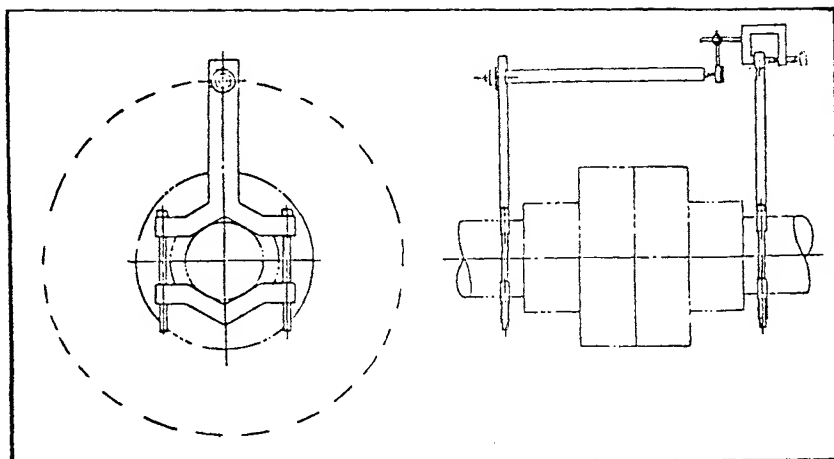


FIGURE 29

Here you see alignment brackets, TS-170 (Figure #29) attached to the shafts with a square extension rod bridging the coupling. Rods can be attached to either or both brackets.

Note that the dial indicator is attached to a bracket. If it has to be attached to a rod, put it as close as possible to the bracket. This way its weight will not affect the reading.

As shown, with its button on the end of the rod, the dial indicator is set to measure angular misalignment.

There are several advantages in using alignment brackets. These are:

1. When taking angular alignment readings, the circle through which the dial indicator button rotates as shown in the dotted line is very large compared to the circle it would make if it was on the face of the coupling hub. The larger the circle, the closer and easier the alignment becomes. For example, to align the shaft to specifications (3-ten thousandths of an inch per inch), the dial reading on a 3" diameter coupling hub would have to be less than one-thousandth. On a 15" diameter circle, a dial reading of $4\frac{1}{2}$ thousandths would meet the specs.

2. The coupling does not have to be open. This is important on hot check alignment where the alignment must be checked before the machine starts to cool down.
3. Using the brackets over a closed coupling makes it easier to turn the shafts together.

The TS-170 brackets are only 3/8" thick. They were designed for use on 1½ to 4" Diameter Shafts where there is very little space between the coupling and the machine.

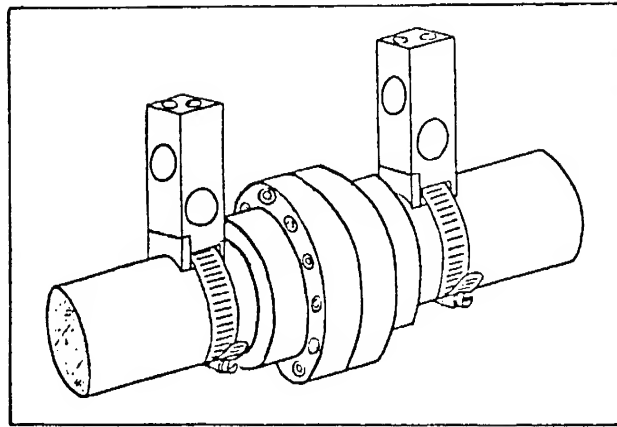


FIGURE 30

Alignment blocks TS-348 can also be used as brackets. See Figure #30. They are 3/4" square. But they can be used on 1 to 10" diameter shafts.

Whatever brackets are used, check them for sag and record the amount so it can be accounted for in readings of parallel alignment in elevation. This is the only reading where the weight of the extension rods or the dial indicator can make a significant difference.

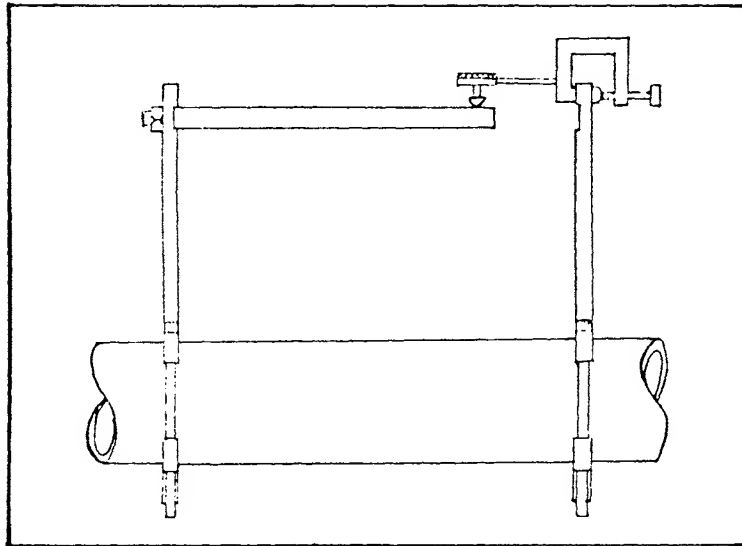


FIGURE 31

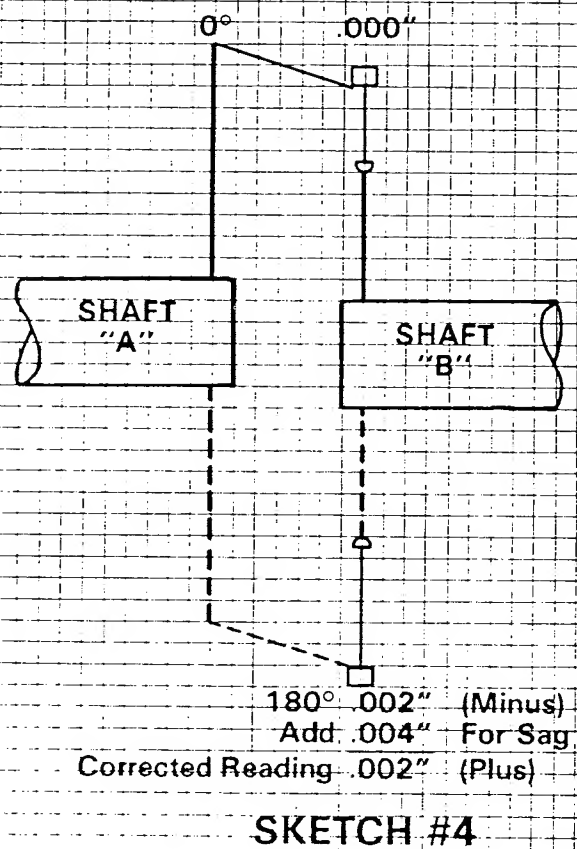
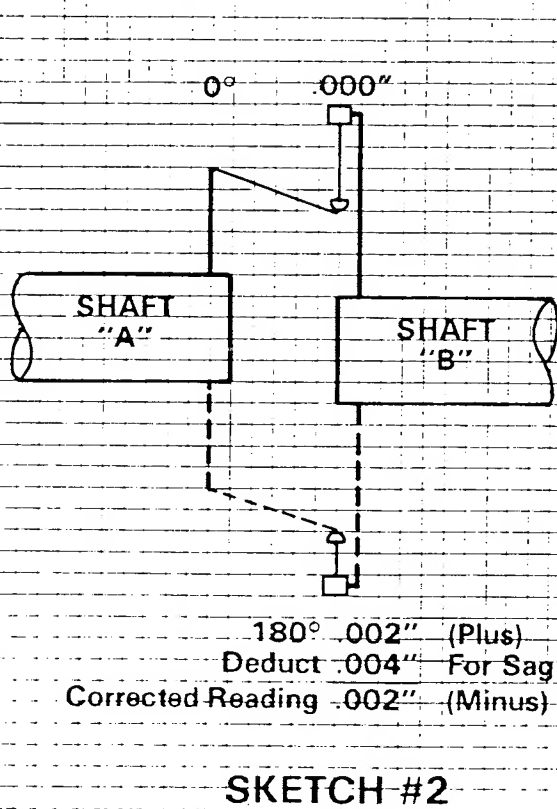
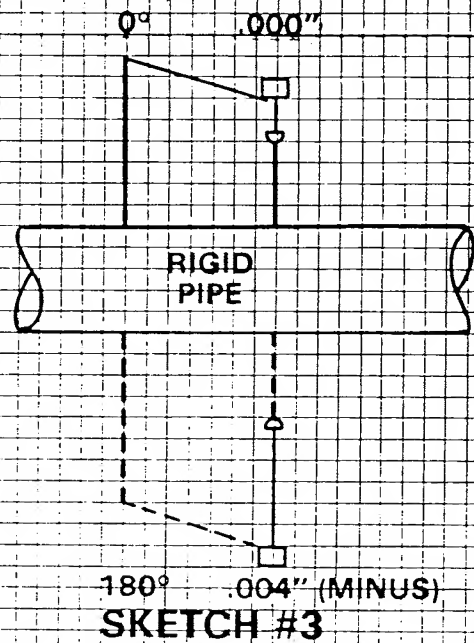
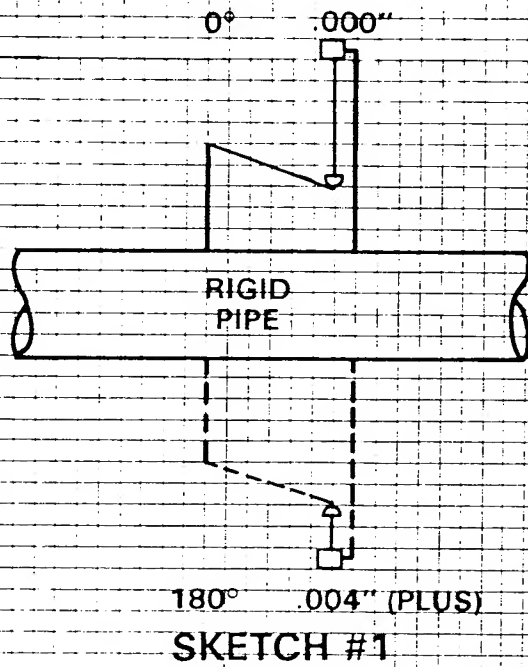
To check the brackets, assemble them on a piece of rigid pipe with the extension rods and dial indicator in place (See Figure #31). The pipe should be approximately 2" in diameter.

With the brackets on top, the dial indicator should be set with its button on top of the extension rod.

Set the dial at 0. Rotate the pipe 180° so the brackets and dial are on the bottom. Again, check the indicator. Since the pipe is rigid, any change in the reading can be attributed to sag or looseness. If sag is indicated, check for looseness and retest.

NOTES

ALIGNMENT BRACKET SAG



COMPENSATING FOR ALIGNMENT BRACKET SAG

In the sketches on page 32, the dial indicator shaft extension and bracket rod sag are scaled. Each division represents .001".

In the sag test in sketch #1 the indicator is attached to the bracket with its button on the extension rod. In the top position the weight of the rod causes it to hang down .002" toward the pipe. When turned 180° to the bottom, the rod will hang down .002" away from the pipe. As shown by the length of the indicator shaft, the button has been pushed in to show total sag is plus .004".

Transferring this set up to the machine as shown in sketch #2 with shaft "B" .001" below Shaft "A", the indicator will show plus .002" in the bottom position. Deduct .004" for "sag" and the corrected reading is minus .002" which is correct for .001" shaft offset when the dial is attached to the low shaft.

The minus .002" reading must be divided by 2 as you will see in the next section of the video tape.

In sketch #3 the sag test is made with the indicator attached to the extension rod. In the 180° position, the indicator will hang down resulting in a minus .004" reading.

As shown in sketch #4 a minus sag test reading must be added to the alignment check reading to obtain the correct reading.

The brackets and indicator must be assembled on the machine exactly as they were sag tested and the indicator button should be compressed the same amount.

Good practice would be to fit them to the machine first then remove them for the sag test.

Another way to correct for sag would be to add or subtract the sag when setting the indicator dial in the top position on the machine.

SECTION THREE

NOTES

SECTION THREE

THE FOUR EASY STEPS TO GOOD SHAFT ALIGNMENT

Now, we will take actual alignment readings on a close coupled reciprocating compressor and motor.

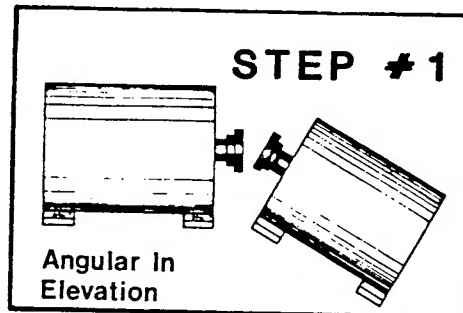


FIGURE 32

We start with alignment step #1, "Angular in Elevation" (Figure 32). Mount the alignment brackets on the shaft with a rod extending across the coupling.

Our dial indicator has a range of 200 thousandths. Mount it on the bracket with its button on the end of the extension rod and compress it to approximately half its range. Now it can register up to .100" plus or .100" minus. If the button moves out, it goes to minus.

At the top, set the dial indicator on 0. Now rotate the shafts 360° several times and check to see if it consistently returns to 0.

Repeatability is important. Never proceed until repeatability is established both in the set up and when taking alignment readings.

Always rotate the shafts in the same direction. If readings do not repeat, it may be because one or both shafts are not being held against their thrust bearings.

Next rotate 180° to the bottom and check for angular misalignment. The reading at the bottom is plus .004". Rotate again and recheck both top and bottom.

While double checking this reading, rotate the shafts slowly and watch the dial movement to verify that it is plus and not minus at the bottom. It's easy to be fooled. If it still shows plus .004" at the bottom, it means the dial button has been squeezed in .004". So the coupling hub faces are .004" further apart at the top than at the bottom.

From the shaft center line to the center line of the extension rod measures $5\frac{1}{2}$ ". Double this is 11". So the circle made by the dial indicator is 11". Divide this into the distance between the front and rear motor hold down bolts which is 14". It will go 1.27 times, so 1.27 times the angular misalignment (.004") is .005". Put this amount of shim stock under the rear motor footings.

Now recheck the angular alignment top to bottom. But, first tighten all hold down bolts. Before any alignment check, always tighten all the hold down bolts as tight as you intend to leave them at the end of the job.

The recheck shows the larger opening is still at the top but is now .001". With the dial making an 11" circle, a reading as high as .0033" would meet the allowable angular tolerance.

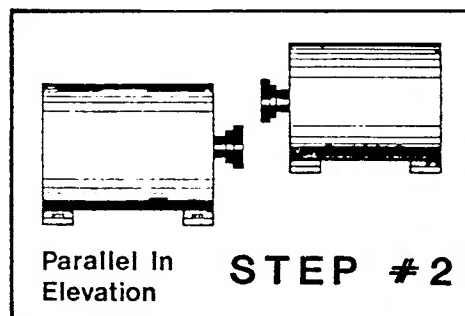


FIGURE 33

Step #2 is parallel in elevation (Figure 33). With angular measurements, we have been using the full dial indicator readings to determine the amount of movement required to make the correction.

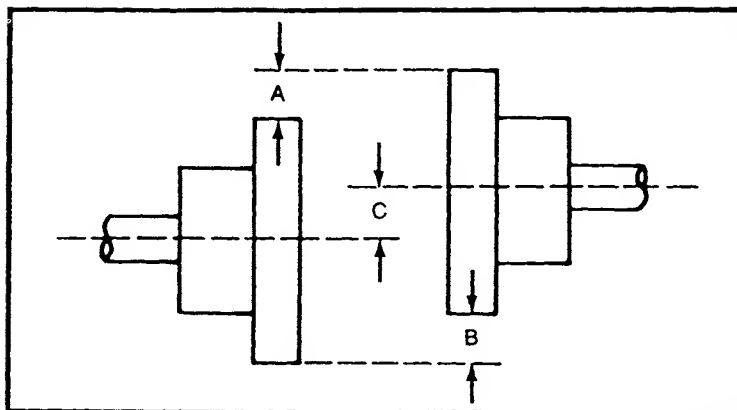


FIGURE 34

With parallel measurements, the dial reading must be divided by two. The reason can be seen in Figure 34.

The indicator will read the sum of A and B, but the required shaft adjustment is only one-half of this as shown at C. This also applies when using the brackets.

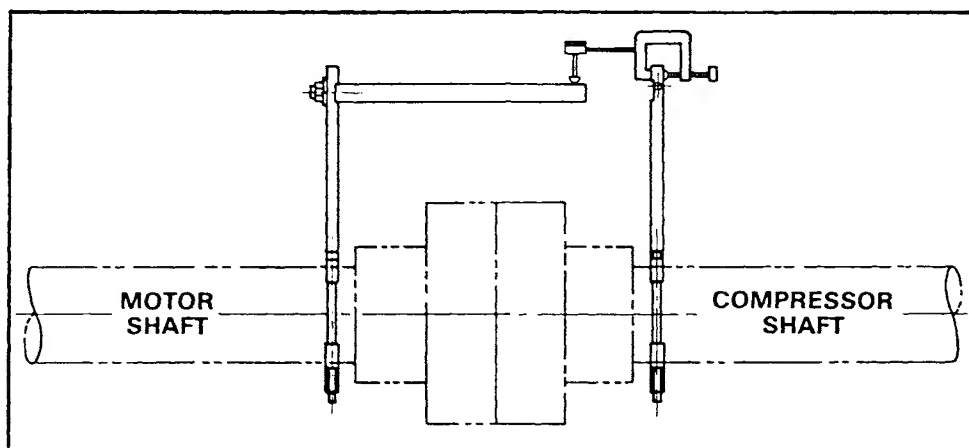


FIGURE 35

Now getting back to the machine, attach the dial indicator to measure parallel alignment in elevation. (Figure 35). With the brackets on top, place the dial indicator button on top of the extension rod. Compress the dial to the middle of its range and set it to zero. Rotate the shafts and check for repeatability. Rotate 180° to the bottom and check the reading. The dial is upside down so use a mirror and

flashlight to read it. It reads plus .020". Again check for repeatability at the top and bottom.

The plus .020" reading must be divided by two. Since it is a plus reading and the dial is attached to the compressor shaft, it means the motor is .010" low.

Put a .010" shim under each motor footing to raise it straight up. To keep the motor from moving side to side or end to end, loosen no more than two hold-down bolts at once. Pry the motor up, slip the shims in and retighten the bolts before moving to the other footings.

Always take the dial indicator off the bracket when moving the machine.

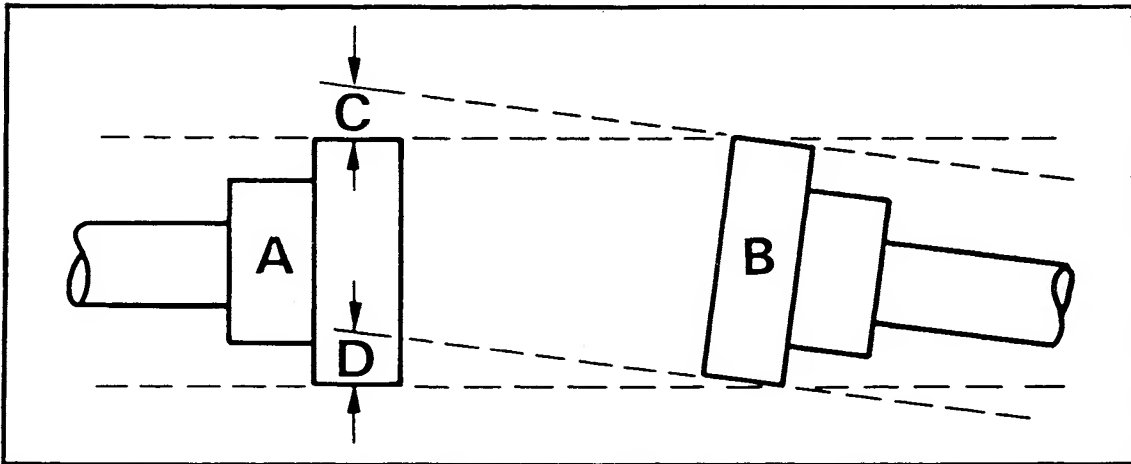


FIGURE 36

Figure 36 shows a condition you should be aware of. It is possible to indicate close parallel alignment when both angular and parallel alignment are very bad.

A dial indicator attached to coupling A with its button on the rim of coupling B, would indicate reasonably good parallel alignment. If the dial is attached to coupling B with its button on the rim of coupling A, the sum of the distances C and D would be read. This would indicate gross parallel misalignment. This also applies when using the brackets. This is another reason why good angular alignment must be obtained before parallel alignment is attempted.

With the motor raised .010" recheck parallel alignment in elevation.

With zero at the top, the dial now reads .002" at the bottom. Actual misalignment is only half of this so it is well within the allowable tolerance for parallel alignment which is .002 inch.

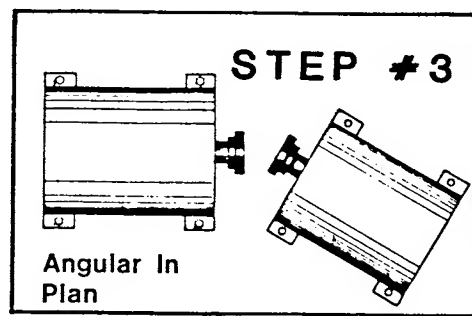


FIGURE 37

Our next move is step #3 "Angular in Plan". See Figure 37.

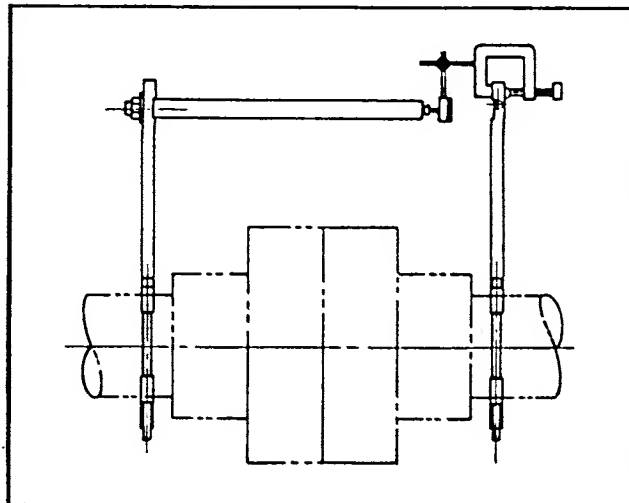


FIGURE 38

Again set the dial so its button is against the end of the extension rod. See Figure 38. With the brackets in the horizontal position on

this side, set the dial at zero. Turn the shafts 180° and check for angular misalignment. It reads plus .016" on the far side. This means the largest opening is on this side.

The method of calculating the required move to correct angular misalignment in evaluation can also be used to correct this angular misalignment in plan. You recall we previously divided the diameter of the circle the dial button is making into the distance between front and rear motor hold-down bolts and the answer was 1.27. So, 1.27 times .016" shows we must move the rear end of the motor over toward the open side of the coupling .020".

First we must decide on a pivot point. The recommended distance between these coupling hubs is 2 15/16". It measures 2.968", so we can afford to let it close a little as we adjust the angular misalignment. This means we should pivot on the front foot on the closed side of the coupling.

Before loosening any bolts, set the dial indicator with its button on the rear footing on the side of the motor with the larger coupling opening. Point it directly in toward the hold-down bolt. Set the dial at zero and move the button in and out several times to make sure it returns to zero and that it makes good contact against the footing.

Now loosen all the motor hold-down bolts. Leave the one at the pivot point snug. The other bolts should be fairly loose.

To move the equipment over against the indicator, it is best to use a screwjack. It gives a smooth and gradual movement. Hydraulic jacks build up pressure until they overcome the friction, then the equipment jumps more than the required movement.

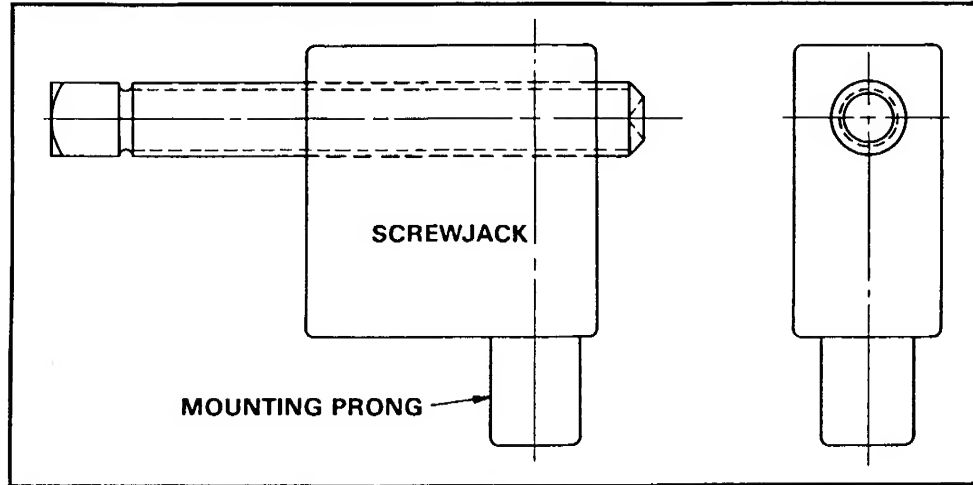


FIGURE 39

The Carrier screwjack Part Number, T11286-A, is shown in Figure 39. Most centrifugal machines have holes in the sole plates to fit the mounting prong. If the job does not have this setup, then you have to use your ingenuity.

We have tack welded heavy duty hex nuts to the base on this machine and will use one-half inch square head set screws for screwjacks.

As the screwjack is turned, watch the dial closely. When it gets to plus .020", stop and tighten the hold-down bolts. Watch the dial. It may change as the bolts are tightened.

Recheck angular in plan alignment. It is now .0015". On this 11" circle, .0033" would be good enough to meet the angular alignment tolerance which is .0003" per inch.

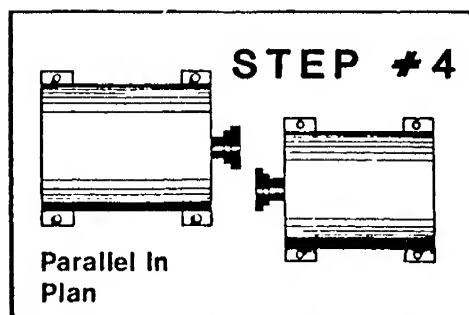


FIGURE 40

The fourth and final step is "Parallel In Plan". (Figure 40).

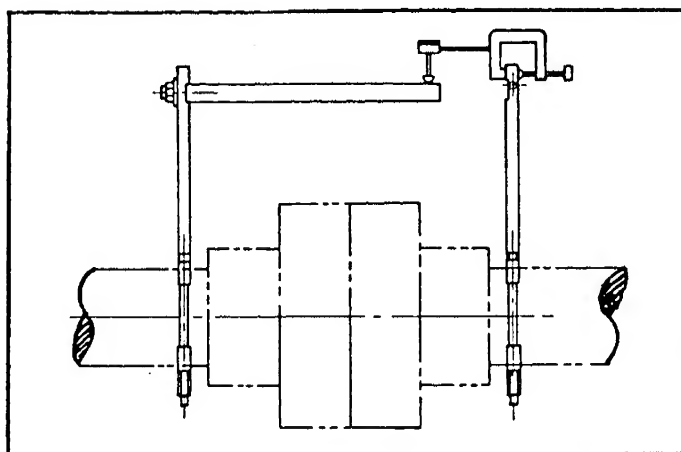


FIGURE 41

For this parallel reading, install the indicator with its button on the top side of the extension bar. See Figure 41. Now, rotate the shafts until the brackets are in a horizontal plane on this side. Set the dial at zero.

Assuming you have repeatability, rotate the shafts so the brackets are horizontal on the opposite side.

The dial reading is now plus .022". If it repeats after several checks, it means the motor must be moved .011" towards this side.

To make an exact move, again use the dial indicator and screwjack on the motor footings.

Since we have only one dial indicator on hand, we will move one end first and then the other.

Remember, the pivot point must remain on the same side for each move.

With all four alignment steps completed, recheck the four positions and record the results.

SECTION 3

WRITTEN TEST

1. When checking parallel alignment in elevation, what tools are handy to read the dial when it is in the bottom position?

1. _____ 2. _____

2. The dial indicator should be removed from the coupling or brackets before making alignment adjustments to:

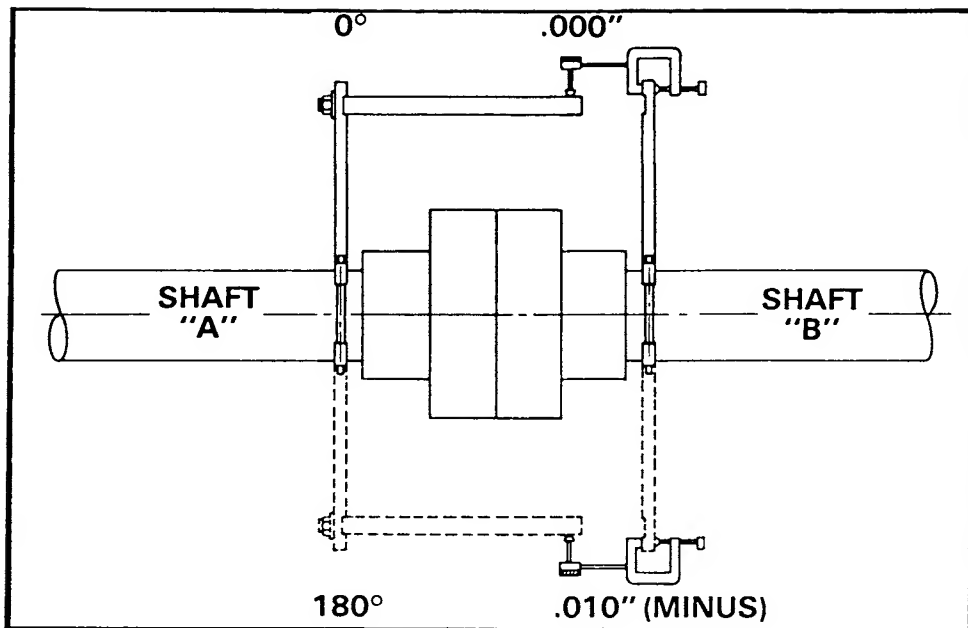
- ☐ Reset it
- ☐ Avoid damaging it
- ☐ Relocate it

3. When the dial indicator button is pressed in toward the dial, will the dial read plus or minus.

☐ Plus ☐ Minus

4. Circle the numbers of the items which could cause lack of repeatability when taking dial indicator readings.

- 1. Shafts not held against thrust bearings.
- 2. Changing direction of shaft rotation.
- 3. Loose alignment bracket.
- 4. Loose extension rod.
- 5. Loose mounting of indicator.
- 6. Button loose on indicator shaft threads.
- 7. Damaged or sticky indicator.
- 8. Grasping alignment bracket to turn shaft.



5. In the above sketch (elevation view), which shaft is low?
 - ☐ Shaft "A"
 - ☐ Shaft "B"

6. How low is the low shaft?

_____ "

7. If parallel alignment readings are not the same when taken from shaft "A" to shaft "B" as they were when taken from shaft "B" to shaft "A", what is the most likely cause?
 - ☐ Bent shaft.
 - ☐ Angular misalignment.
 - ☐ Indicator malfunction.

ALIGNMENT REPORT

JOB NAME: _____

MODEL NO. _____

JOB NUMBER: _____

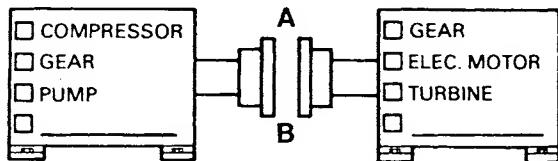
SERIAL NO. _____

DATE: _____

ALIGNED BY: _____

HOT CHECK ☐ COLD CHECK ☐

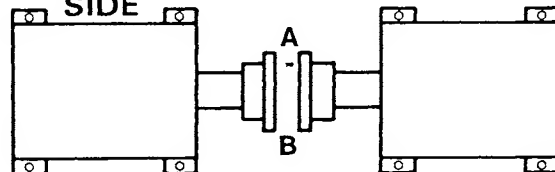
STEP #1 ANGULAR IN ELEVATION



☐ IS OPEN _____" MORE THAN ☐
READINGS TAKEN ON _____" CIRCLE.

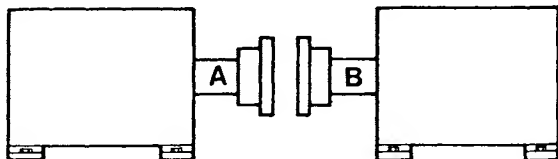
STEP #3 ANGULAR IN PLAN

DISCHARGE
SIDE



☐ IS OPEN _____" MORE THAN ☐
READINGS TAKEN ON _____" CIRCLE.

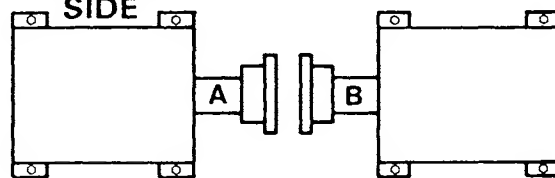
STEP #2 PARALLEL IN ELEVATION



SHAFT ☐ IS _____" HIGHER THAN ☐.

STEP #4 PARALLEL IN PLAN

DISCHARGE
SIDE



SHAFT ☐ IS OFFSET _____"
TOWARD DISCHARGE SIDE.

INSTRUCTIONS:

1. PREPARE SEPARATE SHEET FOR EACH COMPLETE COUPLING ALIGNED.
2. CHECK SQUARES TO INDICATE COMPONENTS BEING ALIGNED.
3. IN STEP #4, IF SHAFT "A" IS NOT COMPRESSOR SHAFT, THEN STRIKE OUT "TOWARD DISCHARGE SIDE".

SECTION FOUR

NOTES

SECTION FOUR

THE FOUR EASY STEPS TO GOOD SHAFT ALIGNMENT

Up to this point, we have talked about aligning the shafts as close as possible to zero on the dial indicator.

There will be occasions, however, to intentionally misalign the shafts when the machine is cold so they will move into good alignment as operating temperatures take over.

Cast iron and steel will expand or shrink approximately .000006" per degree fahrenheit change in temperature per inch of material length. Therefore, if the shaft's center is 20 inches above the bottom of the footings and the operating temperature is 50 degrees above the temperature at which the alignment was made, then you multiply .000006" x 50 x 20 and it shows that when the machine comes up to temperature, the shaft will have moved up approximately six thousandths of an inch.

Most equipment can be aligned as close to zero as possible and operated until it reaches normal operating temperature. Then shut down and check the alignment as quickly as possible. You can try to realign the machine before it cools down too far from operating temperature or wait and let it cool all the way to room temperature, then reset it to compensate for the changes you now know occur.

Turbines and other equipment which operate at very high temperatures must be initially set out of alignment the amount recommended by the manufacturer or the amount calculated as previously discussed.

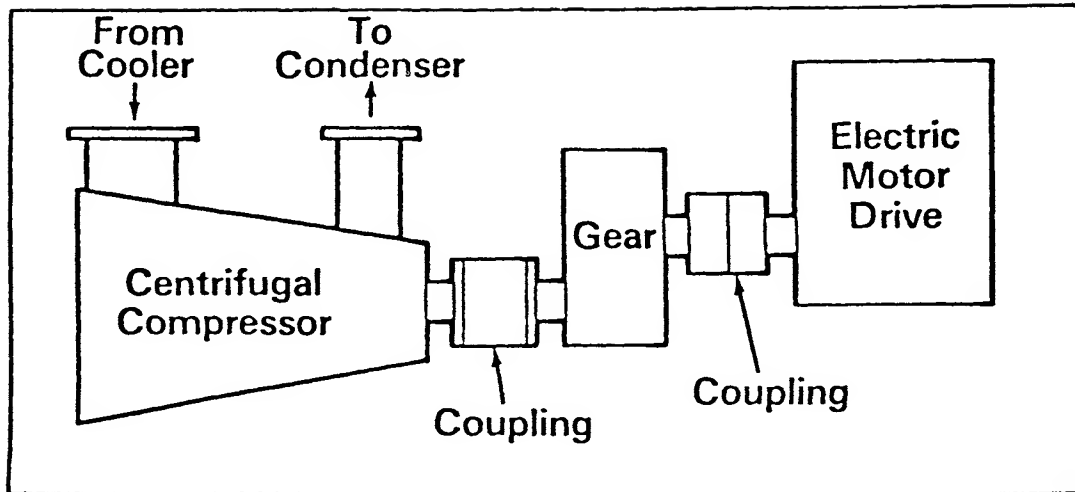


FIGURE 42

Turbines, electric motors, gears, gas engines and water pumps will normally move straight up and down. Centrifugal refrigeration compressors (Figure 42) will move down on the suction end and up at the discharge end. If the compressor is close coupled to the cooler and condenser, it will tend to move toward the cooler at the suction end and away from the condenser at the discharge end.

Estimates of machine changes caused by temperature changes are really just estimates. No machine is really aligned until you have checked the alignment at operating temperature, made the necessary adjustments and rechecked again at operating temperature.

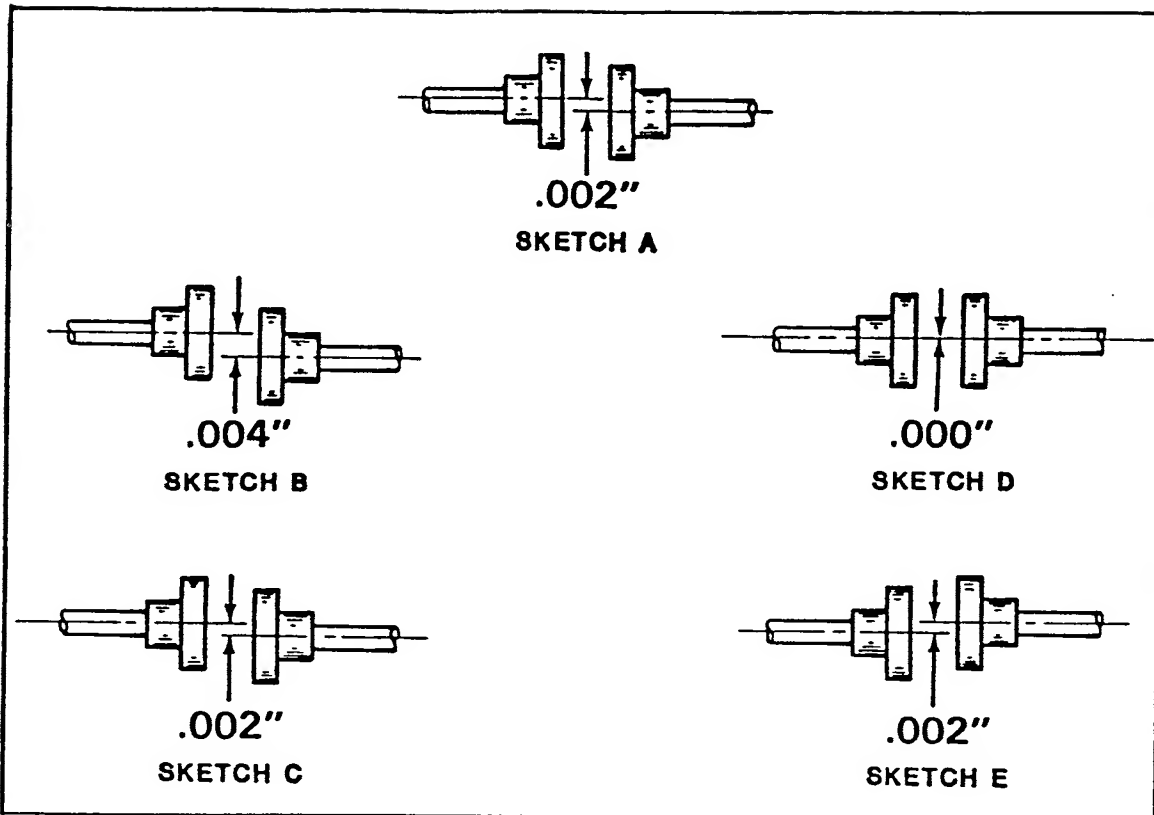


FIGURE 43

On all alignment, you should take advantage of the allowable tolerances, as shown in Figure 43. Parallel tolerance is .002" (Sketch "A"). If you know which piece of equipment will expand the most and know this expansion is going to be at least two thousandths, then you can set its shaft four thousandths low (Sketch "B"). If it only expands two thousandths, it will be within tolerance (Sketch "C"). If it expands four thousandths, it will be dead on (Sketch "D"). If it expands six thousandths, it is still within tolerance (Sketch "E"). So you actually have six thousands to play with.

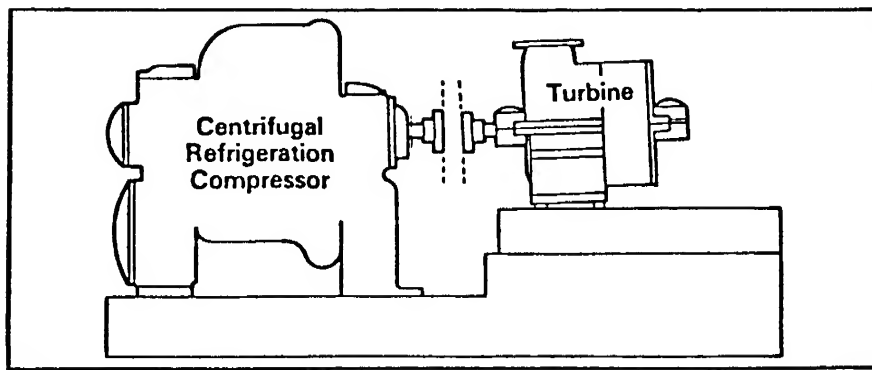


FIGURE 44

The same reasoning applies to angular alignment. For example, with centrifugal compressors, the suction end cools and moves down while the discharge end heats and moves up. Therefore, if you set the coupling dead on, top to bottom, it will always operate open at the top, so the initial alignment should be open at the bottom, see Figure 44. By taking advantage of the tolerances and calculating for temperature changes, the movement required at the hot check will be very little and possibly none at all.

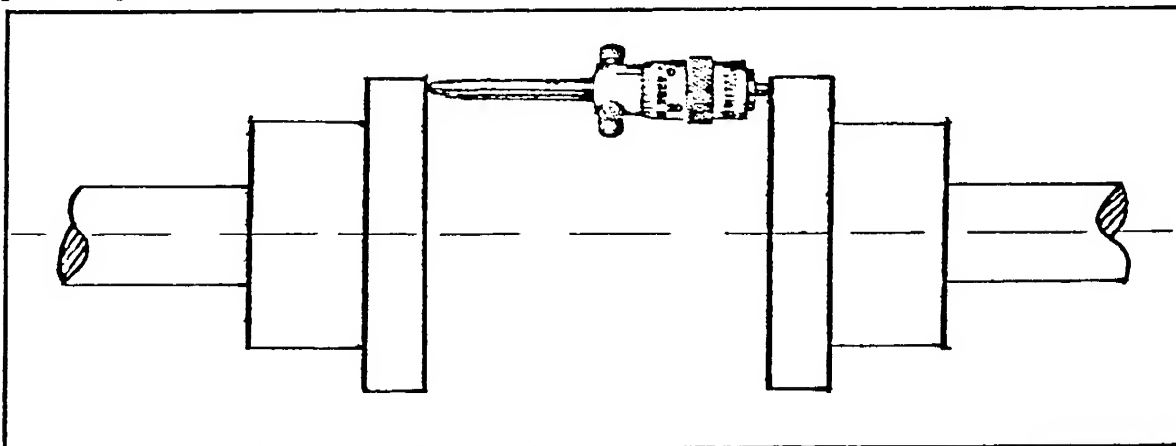


FIGURE 45

Now, let's talk about what can happen when you have to take angular alignment readings off the face of the coupling hubs using inside micrometers (Figure 45), thickness gauges, taper gauges or telescope gauges. (THIS DOES NOT APPLY WHEN USING THE DIAL INDICATOR). Coupling hub faces are seldom perfectly true and are frequently damaged by careless handling.

Readings should be taken 180° apart, top to bottom and side to side and the coupling hubs should be marked so they can be rotated together always turning in the same direction.

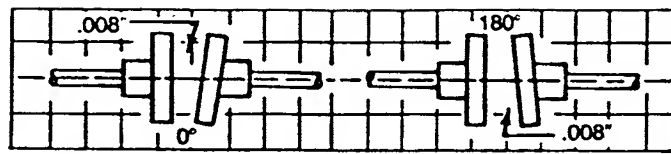


FIGURE 46

In Figure 46 the shafts are well aligned but one coupling face is at an angle to the shaft. By rotating the two shafts together 180°, the larger opening just changes sides. Therefore, if the indicated misalignment changes from side to side, but remains the identical amount, then the shafts are in good alignment.

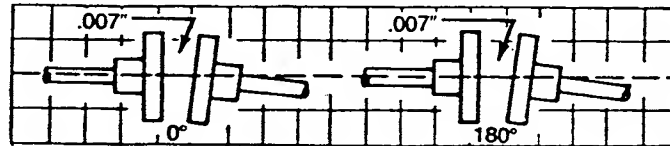


FIGURE 47

In this example (Figure 47), the amount of misalignment remains the same and stays on the same side as the shafts are rotated 180° so we know this is all misalignment.

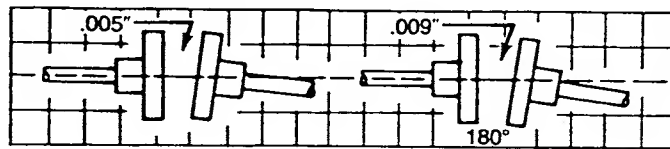


FIGURE 48

In Figure 48 the larger opening remains on the same side as the shafts are rotated 180°, but the amount changes. This means there is some misalignment and some hub face distortion. This can be calculated out by adding the two amounts together and dividing by two, so the actual misalignment in this instance would be seven thousandths.

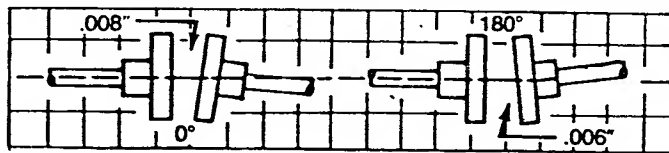


FIGURE 49

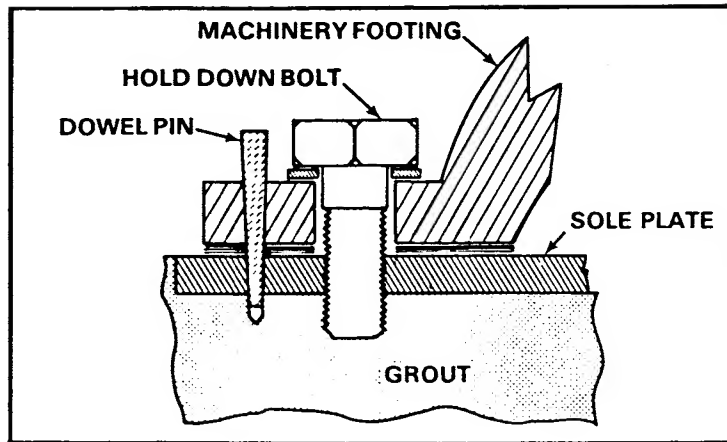
In this last example, (Figure 49) the larger opening changes sides but it also changes amounts. Again, this indicates there is some misalignment and some hub face distortion. This time deduct the smaller amount from the larger amount and divide by two. So, what appeared to be serious misalignment was mostly hub face distortion. The actual misalignment is only .001" which is well within tolerance.

This points out the importance of taking readings 180° apart. As shown in Figure 45, if only one reading had been taken, the adjustment would have been made to compensate for the .008" opening on one side of the coupling hub and the shafts would have been left seriously out of alignment.

Always think safety. Before starting any work around the coupling, be sure to lock out the main starter and tag it, to show the equipment is being worked on. If it is a small starter, it would also be a good idea to remove the fuses.

When alignment is completed, be sure to reinstall the coupling safety guard before the machine is operated.

DOWELING



After alignment has been checked at operating temperature (hot check), and final alignment completed, all machine components must be doweled to their sole plate or base.

Doweling permits exact repositioning of components if they have to be moved.

Size 8 tapered dowel pins are usually furnished with the Carrier centrifugal refrigeration compressor, gear and drive. Use a 13/32" drill bit and a size 8 tapered reamer with straight flutes. Drill a pilot hole then ream it to the final dimension.

Fit the dowel pin so it extends through the sole plate and sufficient length is left above the equipment foot to accommodate removal.

In the event of realignment, it is best to drill new holes rather than try to ream deeper into the old holes.

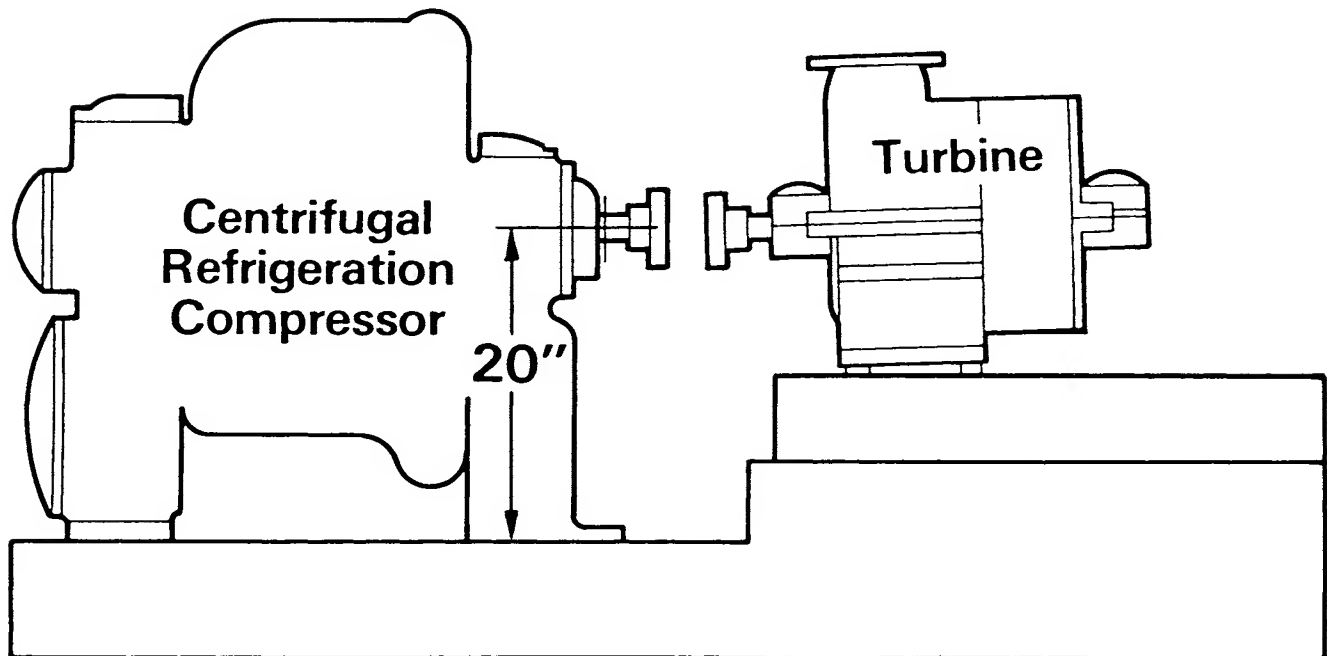
Place the dowel pins as nearly vertical as possible.

Before inserting the dowel pins into the reamed holes, coat them with
while lead or other anti seize, rust preventative compound.

Tap the dowel pins lightly into position with a small machinist's
hammer. A ringing sound will indicate proper seating.

Dowel the suction end only of Carrier compressors. Dowel the gear and
drive in accordance with the manufacturers instructions.

THERMAL CHANGES IN ALIGNMENT

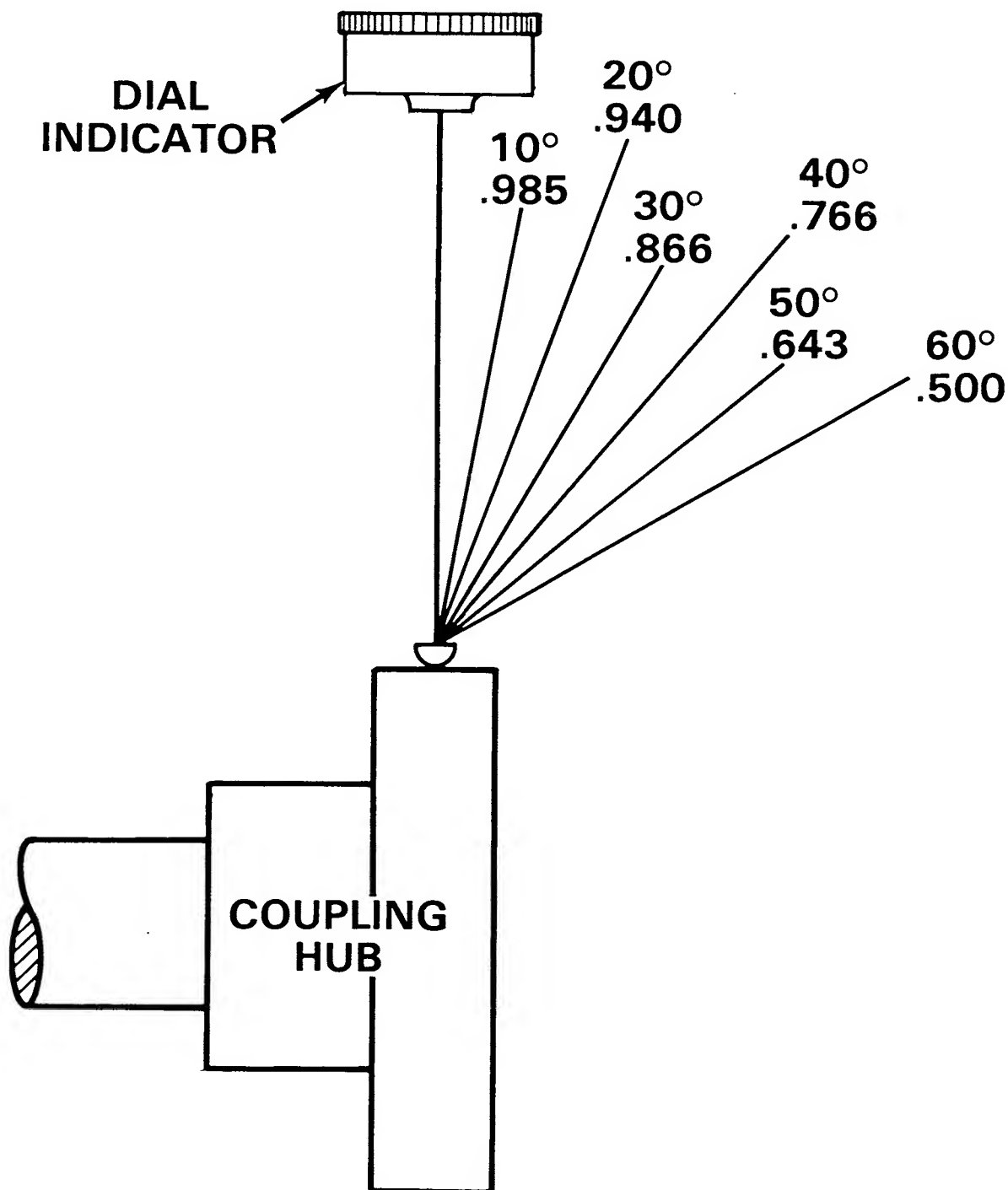


EXAMPLE:

LENGTH OF METAL = 20"
°F TEMPERATURE CHANGE = 50°
COEFFICIENT OF EXPANSION = .000006"

$$20 \times 50 \times .000006'' = .006''$$

CORRECTION FACTORS FOR DIAL INDICATOR SET AT ANGLE TO WORK PIECE



SECTION FOUR
WRITTEN TEST

1. If the distance from the bottom of the machine footing to the shaft centerline is 18", and the average temperature of this 18" of metal is 35° higher with the machine operating than it was shut down, how much higher will the shaft be? Circle one.

.0032" .0045" .006"

.004" .0038 .007"

2. If the dial indicator is set at a 30° angle to the measurement being taken and it reads .015", what should the actual reading be? Circle one:

.010" .0185" .011"

.0165" .0129" .013"

3. What advantage do alignment brackets TS-170 have over alignment blocks TS-348?

4. What advantage do alignment blocks TS-348 have over alignment brackets TS-170?
